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JATE

Journal of Aviation Technology and Engineering 1:1 (2011) 42–54
DOI: 10.5703/1288284314635

Self-Reported Aircraft Noise Complaints and Socioeconomic Demographics in the Greater Philadelphia Region: A Survey of Complaint Data from 1997 to 2009[1]

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Abstract

Aircraft noise complaints are a data set that airport operators can easily collect, review, and analyze. Although this complaint data may not be indicative of total community annoyance, it still may provide insight into local concerns and perception regarding aircraft noise impacts. As has been observed in other research, perception plays a large part in noise annoyance, including areas where the acoustical noise levels are below the 65 db DNL threshold used by the FAA to determine land use compatibility. Noise complaint data collected from the Philadelphia, PA region during the period from 1997 to 2009 was compared to five indicators (per-capita income, median household income, median home values, percent of households considered urban, and approximate annual DNL exposure) to see which of these potential influences might correlate with complaint activity. The strongest relationship was observed between noise exposure (as measured in DNL) with substantially weaker and insignificant correlations observed for socioeconomic indicators and urbanization. The data observed was generally in agreement with previous noise annoyance research and also suggested that while DNL may correlate with complainant activity, it does not explain all of the variance observed.

Keywords: aircraft, airport, noise, annoyance, complaints, demographics, social variables

Introduction

In recent years, overall aircraft noise exposure worldwide has decreased, largely due to the introduction of high-bypass turbofan jet engines and the gradual phase-out of older Stage II jets. The International Air Transport Association (IATA) estimates that aircraft are now 20 dB quieter than they were in the mid-1970s (2004). Similarly, it was estimated by the Federal Aviation Administration (FAA) that the 1999 phase-out of the loudest Stage II airliners would result in an 85% reduction in populations exposed to aircraft noise levels exceeding 65 dB DNL when compared to 1990 estimates (Eldred, 1998). At the same time, many airports have seen a shift from a small volume of loud aircraft to a larger volume of quiet

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aircraft as the number of aircraft operations has increased. Since DNL is an average of noise exposure, the DNL levels may remain constant or even be reduced while the number of noise events increases.

Most airports have at least an informal system of responding to resident noise complaints, but many airports also catalogue this data to observe historical trends and to identify the type of flight activity which has proven bothersome to residents in specific locations. Airport Noise and Operations Management System (NOMS) data are used to measure noise levels in given communities and observe the flight activity near where complaints have occurred, plus collect historical complaint data. NOMS data provide a fuller perspective of local noise impacts and trends for a given airport as it synthesizes sound measurements, flight tracks, operational data and complainant data into a single queryable database. In 1997, the City of Philadelphia Division of Aviation installed its first NOMS system (called TAMIS) at Philadelphia International Airport, which was subsequently upgraded to an enhanced version of TAMIS named Airscene in 2009.

It is important to note that the majority of aircraft noise research has focused on annoyance, rather than complaints (Maziul, Job, & Vogt, 2005). The literature indicates that aircraft noise complaints have been shown to not fully capture the full extent of annoyance (Fields, 1992; Guski, 1999), may be influenced by physiological or psychological factors (Stansfeld, 1992), and are prone to over-represent individuals who have a propensity to complain (Hume, Morley, Terranova, & Thomas, 2002).

However, noise complaint records are a data set that is readily available to many airport operators, and this paper examines what, if any, relationships might exist between the number of complainant households and the area demographics. This may prove beneficial in seeing what uses might be found in analyzing complaint data for a given airport.

Specifically, this paper reviews the demographics of noise complainants in the Philadelphia region to see if the socioeconomic data are similar to what has previously been reported in the literature regarding annoyance. Also, the data will be examined to see if complaints were more common from areas that had higher levels of noise exposure.

Background and Literature Review

One of the difficulties in assessing noise impacts, particularly at levels where direct health hazards are not a major factor, is that noise is largely an issue of sensory perception and personal preference. Noise, by its definition, is an unpleasant or unwanted sound. A sound characterized as noise can be accurately measured as a vibration or a change in air pressure, but what makes it "noise" is a matter of perception. A sound meter in a concert hall could show similar measurements to those taken off the end of a runway, but one is disruptive and the other is not (given that one likes the type of music being played).

Fidell and Pearsons have observed that "a single, purely physical metric that can serve as a universal predictor of the annoyance of noise exposure is unlikely to succeed" because "purely physical measures" cannot accurately predict noise annoyance thresholds (1998, p. 908). Guski estimates "about one third of the variance of annoyance reactions can be 'explained' by the variance of acoustic features, another third by the variance of personal or social variables" (1999, p. 1). As noted by Fidell and Pearsons, two different populations that report that they are highly annoyed with aircraft noise may actually be exposed to very different noise levels and the researchers observe that external influences such as news media, civic organizations and political action can result in people who experience rather low levels of noise exposure "[describing] themselves as highly annoyed" (1998, p. 908). It is evident that non-acoustic factors, both psychological and social, influence the self-reporting of noise annoyance.

A wide variety of psychological and audiological influences come into play when determining noise perception and annoyance. Likely the most well-known research into this is the work of Schultz (1978) which resulted in the so-called Schultz curve. Schultz looked at noise annoyance related to various sound levels (dosage-effect) and found that as noise levels increased, reported annoyance did as well. Schultz's findings were useful in the early years of environmental noise reduction legislation and influenced the 65 dB DNL standard included in Part 150 of the Federal Aviation Regulations (Fidell, 2003). DNL (also sometimes abbreviated L_{dn}) is the abbreviation for Day-Night Average Sound Level, which is the average amount of A-weighted sound energy received over a 24 hour period, with a 10 dB penalty assessed for noise that occurs between the hours of 10:00 PM and 7:00 AM. An annual average of 65 DNL is the noise threshold for which some land use is considered incompatible (such as residential, educational or places of worship) with airport operations under Part 150 of the Federal Aviation Regulations (FARs).

Stansfeld observes that noise complaints and other forms of surveys or questionnaires are not entirely free of bias, as complaints can be influenced by "subject sensitivity" and "negative attitudes towards noise sources" (1992, p. 9). For example, people who view aircraft as a safety hazard or local airport operators as inconsiderate of local communities may translate those views into a high sensitivity to aircraft noise levels. Likewise, local residents may file noise complaints as a result of unrelated factors, such as to express displeasure with proposed airport projects that have little, if any, relationship to noise levels.

Fields has written a detailed discussion on the topic of personal and social variables and aircraft noise annoyance.

The results of 282 noise surveys were reviewed in order to assess what other factors may influence annoyance to aircraft noise, aside from acoustical factors. It was found that demographic variables, such as sex, race, age, income, education, homeownership were not a major influence on noise perception.

Particularly relevant to research into this analysis of complaint data from the Philadelphia region is Field's observation that income and home values did not correlate to an increased sensitivity towards noise; however, he notes:

> In fact, at least four surveys have found that high socioeconomic status leads to more public action (Graf, Meier, Miller, 1974; Goodman and Clary, 1976; McKennell, 1965; Taylor and Hall, 1977). The evidence thus suggests that these socioeconomic status variables do not increase residents' annoyance with a noise, but do increase the likelihood that residents will use their verbal and organizational skills to take action against noise. (1992, p. 18)

Some research has indicated that middle-class individuals are more likely to be noise sensitive than those of other income groups (Stansfeld, 1992). But other work suggests that this tendency is likely attributable to an increased likelihood for those with higher incomes to engage in social and political activism, rather than an actual increased sensitivity to noise (Fields, 1992). This seems to be particularly the case with those individuals which Hume et al. (2002) have called serial complainers; people who complain significantly more than others in the same community. The relationship between complainants' income and education is also specifically discussed by Maziul et al.:

> Already in one of the first Heathrow studies complainants are described as e.g. better educated and holding higher status jobs than non-complainants (McKennell, 1973). Also in an early North American study complainers differed from non-complainers in education, the value of their home[s] and membership in organizations. Consequently, complainers are not viewed as representative of their community (Tracor, 1970). With regards to these findings, complaint behaviour cannot be accepted as an accurate measure of public annoyance, as it is argued that it is not because people with more education and higher occupational status tend to be more annoyed, but because these people are more likely to feel that their complaints will be listened to. . . . It has generally been found that persons, who are older, better educated, have higher income and higher social status, are more prone to express their feelings by the means of complaints and are more often members of an environmental organization than people who do not complain (Borsky, 1979; Guski, 1977; van Wiechen, Franssen, de Jong and Lebret, 2002).

This research will look at the demographics of populations which have reported aircraft noise annoyance by filing complaints with the Philadelphia Airport Noise Office, which serves both the Philadelphia International Airport and Philadelphia Northeast Airport (a general aviation reliever facility). However, by far, most of the complaint data are regarding aircraft operations to and from Philadelphia International Airport.

In particular, household income, per capita income, and median home values will be examined to see if a correlation exists between these socioeconomic indicators and the number of households complaining in a given zip code. Also, the percentage of homes that is considered in an urban setting by the U.S. Census Bureau will be examined to see if a correlation exists between those residing in urban or rural settings. Lastly, the above demographics will be compared to approximate DNL values derived from the modeling of the FAA's New York / New Jersey / Philadelphia Airspace Redesign Project (ARD) to see if the number of complaints increases with noise exposure.

Methodology

This project used data taken from three sources. First, historical complaint data was taken from the Airscene NOMS system in use at the Philadelphia Airport Noise Office (Division of Aviation, 2009). Secondly, population and demographic data was obtained from the U.S. Census Bureau American FactFinder database (U.S. Census Bureau, 2000). This included the following demographic indicators taken from the 2000 U.S. Census for each zip code in which a household filed a noise complaint:

1. Total population
2. Median household income
3. Per capita income
4. Median value of owner-occupied homes
5. Urban and rural populations

This project proposes to describe the overall characteristics of a given zip code population; therefore, the number of households complaining was used, rather than the raw number of complaints. Occasionally, a single household may provide a disproportionately high amount of complaints, which would not necessarily represent the entire population of the given area. For example, one household in a given zip code may file 200 complaints, which is different from 200 households each filing a single complaint.

The goal is to observe a broader community response to noise annoyance rather than the responses of a few individuals who may have an unusually low tolerance for aircraft noise, the so-called serial complainers. It has been noted by Stansfeld that individuals with hypersensitivity to noise are likely to suffer from psychological or physiological conditions that influence their perceptions (1992). In this data set, 17 households in the greater Philadelphia region have submitted more than 50 complaints each and one household submitted 435 complaints, which accounted for 6.2% of all complaints. Similarly, Manchester Airport in the United Kingdom reported that three people were responsible for 41% of their complaints during one year (Hume et al. 2002 cited in Maziul et al., 2005). By utilizing the number of households complaining instead of the total number of complaints received the assessment should be more reflective of the overall community.

In each zip code, the number of households complaining was calculated as a ratio to 10,000 people, as determined from the Census data. The ratio was determined by dividing the number of complainant households by the total population of each zip code and then multiplying it by 10,000.

The complainant household ratio was then compared to the four demographic data sets obtained from the U.S. Census Bureau. Using descriptive statistical analysis, including scatterplots and histograms, that data was reviewed to see if there were any clear relationships observed between the demographics observed and complaints received.

Lastly, to get an approximation of noise exposure for each zip code area, data was derived from the Noise Mitigation Tables from the FAA's Philadelphia ARD (Federal Aviation Administration, 2009). These tables include modeled 2006 and 2011 noise exposure levels (in DNL) for each census tract in the ARD study area. This data set provides a unique opportunity to look at modeled noise exposure on a wider regional level, including areas below 65 dB DNL.

In order to provide a rough estimate of noise exposure for each zip code, the arithmetic mean of the modeled 2006 DNL levels in each complainant census tract was calculated. This averaged data was then rounded to the nearest decibel, which allows for a reasonable approximation of annual DNL for each zip code. A more accurate method would be to take the logarithmic average of the DNL values, but the mean still provides a useful approximation. Because the DNL levels noted are an annual baseline level prior to the implementation of the ARD, actual noise levels experienced will vary based on the status of that project over time. These estimates of community noise exposure were used to ascertain if households located in communities with higher noise levels complained more.

Since a high number of aircraft noise events can cause considerable annoyance even if the DNL values are low (Kohut, 2009; Fields, 1992), it is important to note that at Philadelphia International Airport, the number of aircraft movements has remained fairly consistent during the period reviewed, with an average of approximately 484,000 annual operations.

Limitations of Methodology

For multiple reasons, it should be noted that the complaint data set is likely not representative of a standard population and that the data only describes the complaints received at the Philadelphia Airport Noise Office. As observed in the introduction, measuring aircraft noise annoyance is difficult, particularly when self-selection is used. This is particularly the case with complaints, as the data is collected entirely through self-selection. As discussed by Maziul et al. (2005) multiple studies indicate that many people who are annoyed by aircraft noise do not complain to the airport operator. Therefore, complaints or lack thereof do not necessarily reflect true community annoyance. In short, to accurately represent a standard population, a larger and truly random sample that did not rely on self-reporting would be required. As a survey of complaint data, this data set contains only those zip codes where complaints occurred.

Another limitation is that correlations in the data may not be explained entirely by the relationships observed. For example, if a relationship is observed between income and noise complaints, there are likely multiple factors involved. A more detailed multivariate analysis may provide more insight, but is beyond the scope of this paper.

Also, as noted earlier, external influences can impact noise complaint levels. For example, in 2008, the Philadelphia Airport Noise Office observed a 534.5% increase in complaints from the prior year and this was largely due to resident concerns about the ARD project. Although most areas were not actually experiencing any additional air traffic noise due to the redesign, many residents incorrectly assumed they were adversely impacted. Once the media coverage and public political debate died down, the number of complaints decreased to levels more in line with historical precedent. Complaints based on an expectation that noise will increase have been documented at other airports as well (see Hatfield et al., 1998, and Fidell, Silvati, & Haboly, 2002, as cited in Maziul et al., 2005).

It should also be cautioned that zip codes do not provide a reliable measure for data analysis over the long term. Much like telephone area codes, zip codes are occasionally altered or split for postal reasons, which can change the demographics associated with them. Zip codes were used as the data could be queried from the Airscene database in that format and demographic data was readily available for them.

Lastly, the approximate DNL noise level values are an average for estimating approximate noise exposure within an overall zip code area. This data should not be considered a precise measurement and cannot be used to determine eligibility for noise mitigation.

Results

Description of Data

The data are from the period January 1, 1997 to October 31, 2009 and consist of 7,019 complaints received from

1,712 households in 183 zip codes across three states (Pennsylvania, Delaware and New Jersey). Complainants that did not provide zip code data, zip codes that do not have 2000 Census data and one other zip code (19710) were not included.

Zip code 19710 contains a small population of only 38 people, with a per-capita income of $654,485 and median home value of $1,000,001. It is located approximately 14 miles from Philadelphia International Airport and has a DNL value of approximately 44 dB. During the time that this data was collected, one household filed two complaints. Due to the extremely small population size and very high income and home values, this data created a substantial outlier that skewed the data analysis towards showing relationships between complainant households and income and home values.

Thus, in total, 16 complainant households were not included (0.93% of the total). The breakdown of this discarded data is as follows: 14 households did not provide sufficient address information to determine a zip code; zip code 19456 did not have 2000 Census data available; and zip code 19710 was not included due to its outlier status, as explained above. Another zip code (19709) was outside of the ARD study area but was used for analysis that was not related to DNL. Given the above criteria, the final data set consisted of 1,696 complainant households located in 181 zip codes (n=1,696).

Number of Complainant Households per Zip Code

The mean number of complainant households by zip code was 9.37 and the median was 4, with a range of 166. The kurtosis of the data set was 34.67 and the skewness was 5.24, indicating that the data set was not close to a normal distribution. The positive skew indicates that a few zip codes with a high number of complainant households raised the mean. Approximately 51% of the complainant households were located within 15 zip codes and those located within two zip codes accounted for 16.85% of the total. The histogram in Figure 1 indicates that between 1 and 10 complainant households per zip code was the most common frequency, followed by 10 to 20 households per zip code.

Population of Complainant Zip Codes

The total population of the included zip codes was 4,097,010 people with a mean of 22,635.41 and a median of 19,079. The range was 70,534 with a minimum of 634 people in zip code 08104 and a maximum of 71,169 in zip

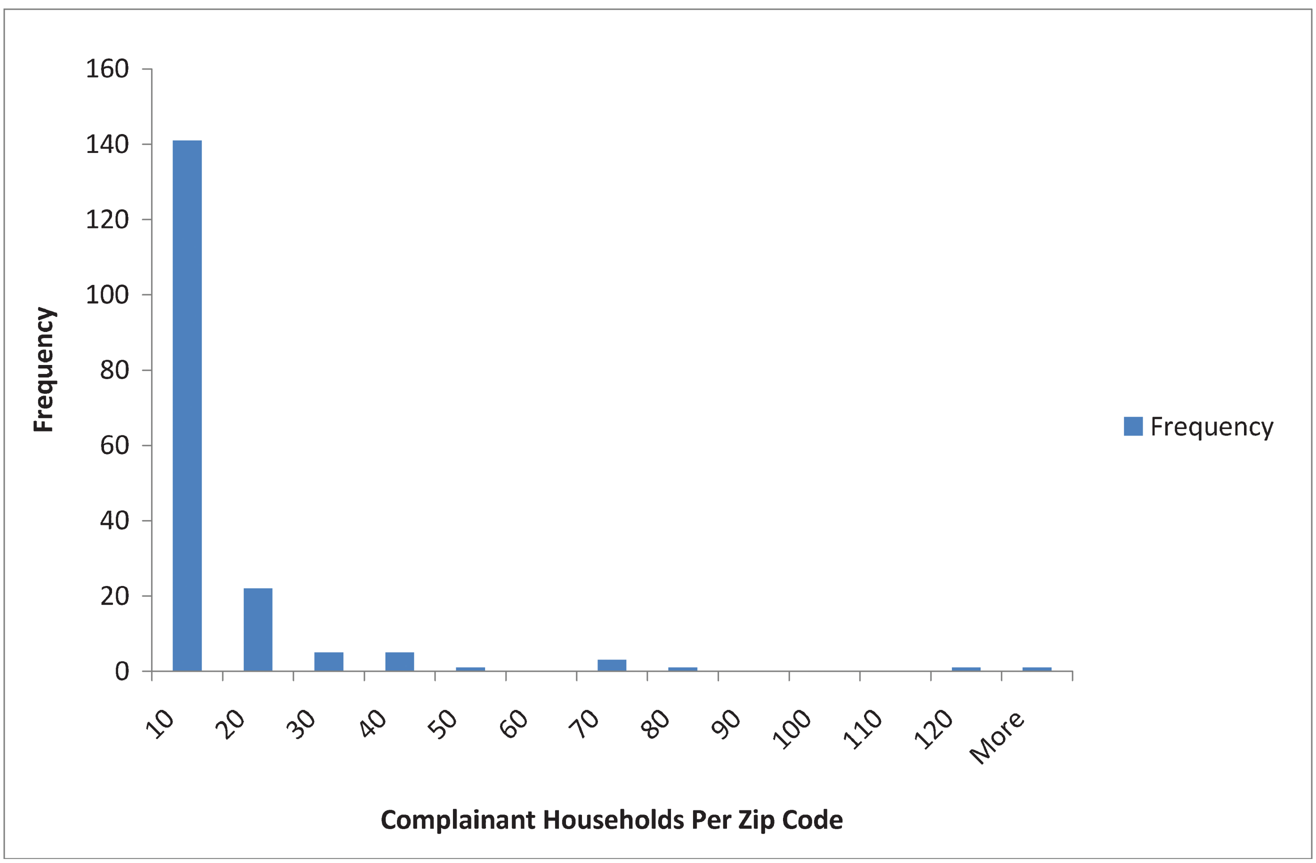

Figure 1. Frequency of complainant households in each zip code.

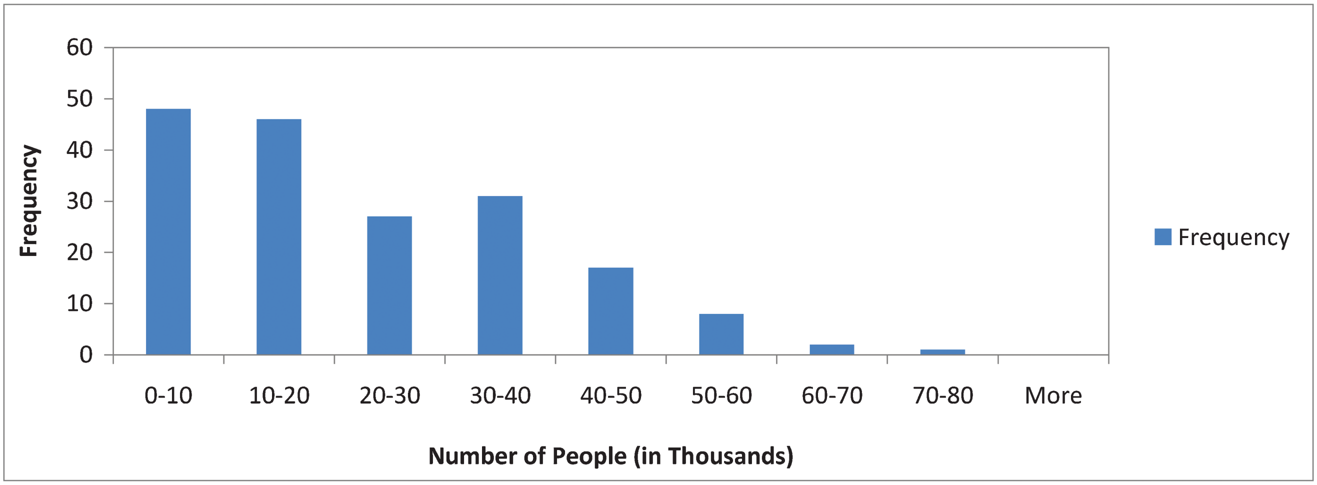

Figure 2. Frequency of populations within complainant zip codes.

code 19143. The kurtosis was -0.06 and skewness was 0.8, which indicates that the mean was raised by a few zip codes that were highly populated, as is visible in Figure 2. Approximately 52% of the zip codes had fewer than 20,000 people and about 94% had fewer than 50,000 residents.

Complainant Household to Population Ratio

This measure was calculated to provide a sense of how many households in a given zip code population filed complaints and to allow for comparisons between zip codes with varied populations. The mean was 6.85 with a median of 2.34 households. The skewness was 4.46 and kurtosis was 23.29, which indicates that a few zip codes with a high number of complainant households raised the mean. The range was 105.34, from a minimum of 0.18 in zip code 19720 to a maximum of 105.52 in zip code 19078. 85% of zip codes had less than 10 complainant households per 10,000 people and approximately 93% had less than 20 complainant households per 10,000 people.

Median Households Income per Zip Code

The median household income (in 1999 dollars) of the zip codes with complainant data was $54,347.94 with a median of $51,150. The highest income was $159,905 in

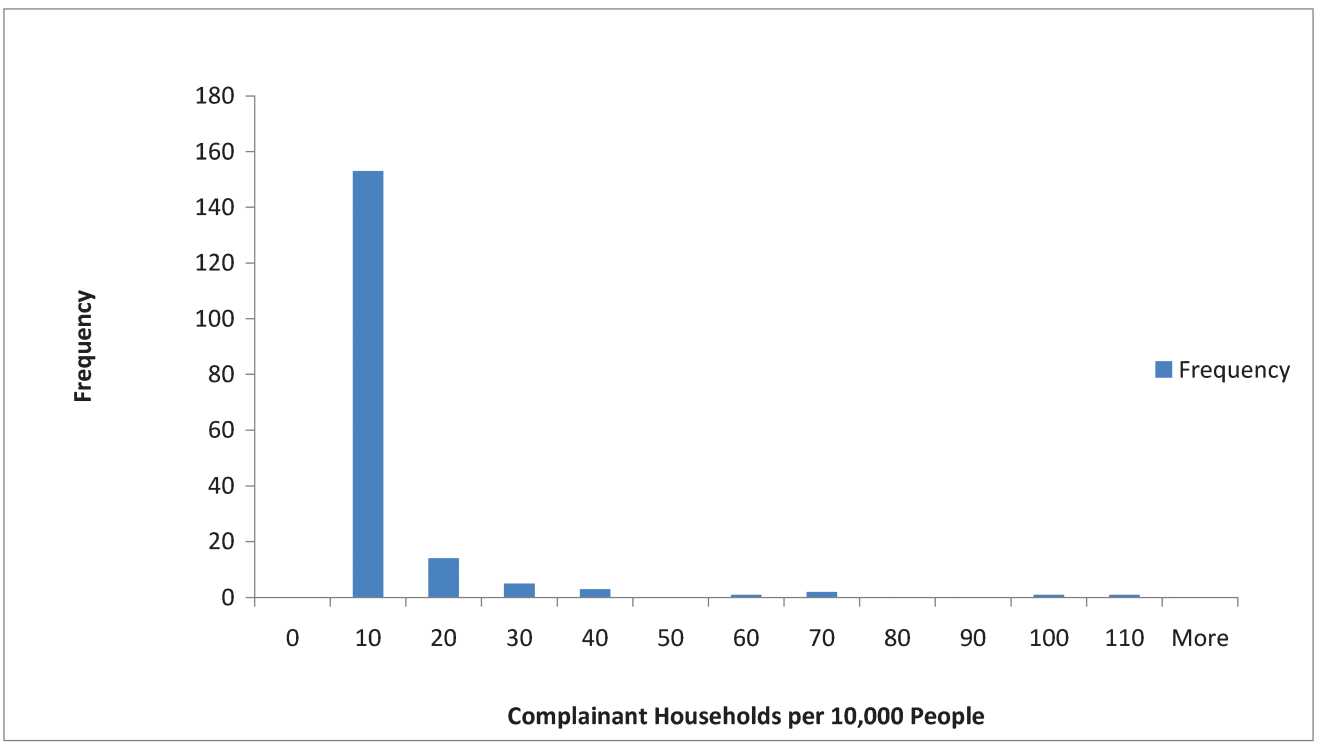

Figure 3. Frequency of complainant households to 10,000 people.

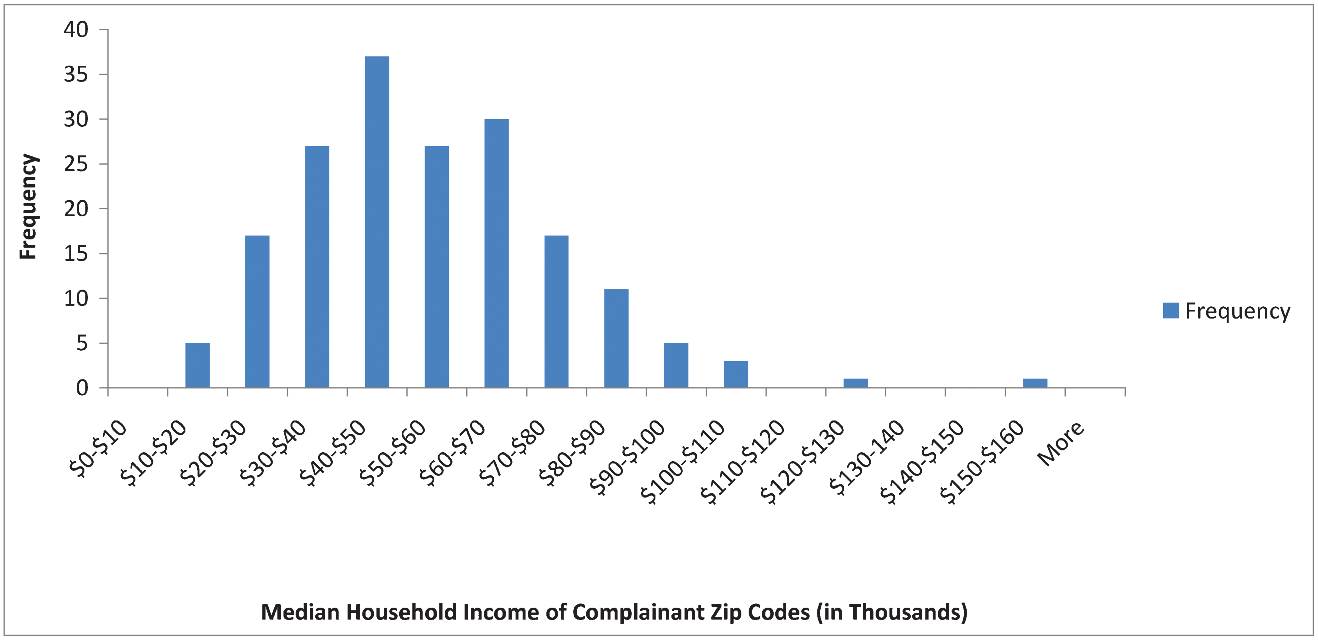

Figure 4. Median household income in complainant zip codes.

zip code 19035 and the minimum was $13,828 in zip code 19133, providing a range of $146,077. The kurtosis was 2.49 with a skewness of 0.98. While this data was normally distributed, a few zip codes with high median household incomes still raised the mean. Approximately 99% of complainant zip codes had a median income under $130,000.

Median Home Values in Zip Codes Filing Complaints

The mean value of homes (in 1999 dollars) for complainant zip codes was $143,548.07 and the median was $122,200. The highest value was $602,300 in zip code 19035 and the lowest was $18,400 in zip code 19133, giving a range of $589,300. The kurtosis was 4.56 and the skewness was 1.61, which is visible in Figure 5, due to most of the homes being within the $0 to $300,000 range. 95% of zip codes with complainant households had median values of $300,000 or less.

Number of Census-Defined Urban Homes in Complainant Zip Codes

The mean number of census-defined urban homes was 22,250.46 and the median was 18,449. The range was 70,565, with that number being the maximum and some zip codes being entirely rural (i.e., having no urban areas). The kurtosis was 0.16 and skewness was 0.75, as is evident in Figure 6.

Related to this statistic was the percent of homes considered urban by the Census Bureau in each complainant zip code. The mean percentage of homes considered as

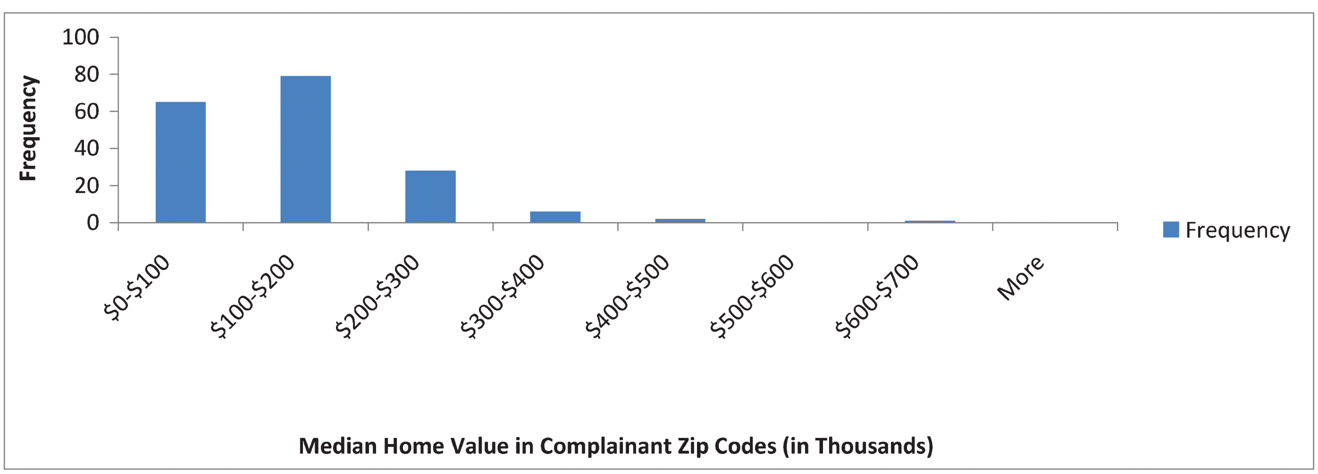

Figure 5. Median home values in complainant zip codes.

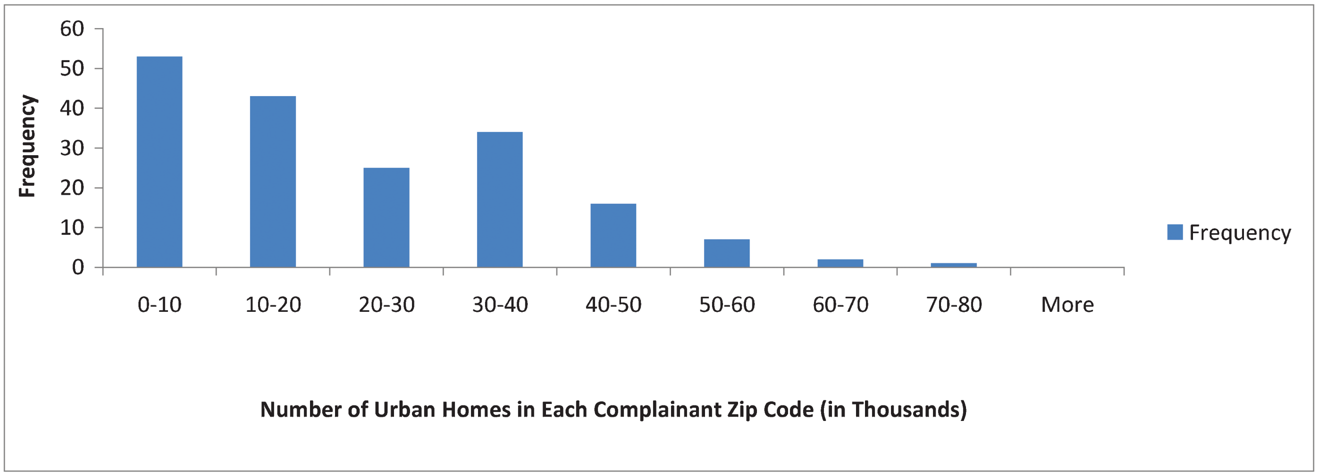

Figure 6. Number of urban homes in each complainant zip code.

urban in each complainant zip code was 95.6%. The kurtosis was 21.45 and skewness was 4.40. 89% of zip codes with complaint data were considered 100% urban.

Approximate DNL in each Complainant Zip Code

The mean approximate DNL for each complainant zip code was 43.79 dB, with a median of 43.77 dB. The minimum was 29.62 dB and the maximum was 58.89 for a range of 29.26 dB. It is important to reiterate here that each zip code's DNL was an approximation based on the mean DNL value of the census tracts where complainant homes were located. The kurtosis was 1.87 and skewness was 0.07. Figure 7 shows a fairly normal distribution of data, centered on the mean. 95% of zip codes fell between 35 dB and 55 dB, with 51% in the 40–45 dB range alone.

Analysis of Data

The three questions examined using this data are as follows:

1. What, if any, relationships exist between measures of socioeconomic status and the number of complaints received from a given zip code, as expressed in the ratio of complainant households to 10,000 people?
2. What, if any, relationships exist between the approximate DNL exposure and the number of complaints received from a given zip code, as expressed in the ratio of complainant households to 10,000 people?
3. Is there any relationship between the percentage of homes considered urban and the ratio of complainant households to 10,000 people?

Measures of Socioeconomic Status versus Complainant Households per 10,000 People

All three socioeconomic measures showed a very low relationship with the number of complainant households. In each case, linear regression of the data showed a coefficient of determination (r^2) of .005 or less, which indicates that around 99.5% or more of the variance in the data was unrelated to the economic variables. Also, the correlation (r) values for all three economic measurements indicate a weak relationship, as indicated in Table 1.

As indicated in Figures 9 through 11, regression analysis indicates a slight positive relationship between economic measures and the number of complainant households per 10,000 people in this data set. This relationship would be consistent with the findings of Fields (1992) and Maziul

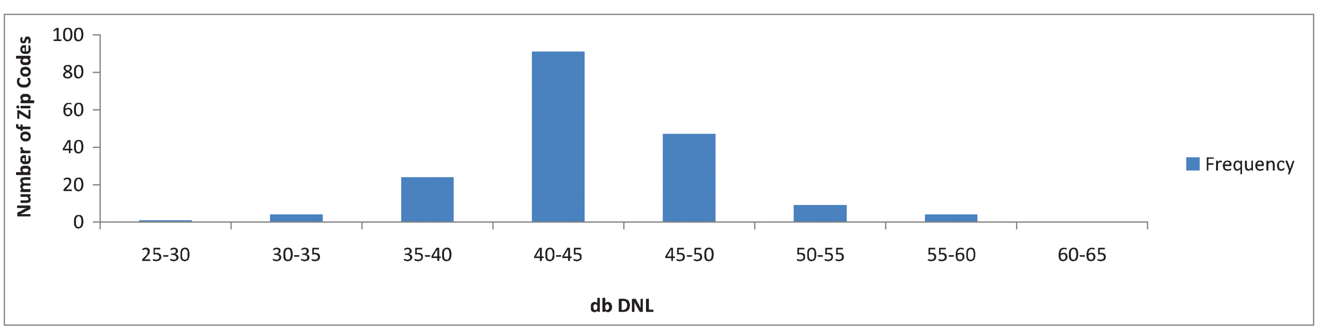

Figure 7. Number of complainant zip codes by average DNL.

Table 1
Correlation Calculations for Socioeconomic Measures versus Complainant Households Ratio

	Correlation Value (r)
Median Home Value (1999 Dollars)	0.03
Median Household Income (1999 Dollars)	0.05
Per Capita Income (1999 Dollars)	0.07

et al. (2005), which were discussed in the background section. However, given the low r values, it can be said that this data shows little relationship between these three economic measures and the complainant household ratio. Therefore, other factors, such as personal and social variables could be more dominant than economic influences (Guski, 1999; Fields, 1992).

Approximate DNL Exposure vs. Complainant Household Ratio

The approximate DNL value for each zip code did have a stronger correlation (r) value than any of the socioeconomic factors, with r=.27. Using simple linear regression (see Figure 11), the DNL data showed an r^2 of .08, which indicates that about 8% of the variance was related to the approximate DNL exposure. However, when a logarithmic trendline was applied (see Figure 12), the r^2 value increased to approximately .14, which indicates nearly 14% of the variance was related to the DNL. Also, given the logarithmic curve, a steep increase is observable between 40 and 45 dB DNL. Table 2 provides the mean number of complainant households per 10,000 people for varying average DNL levels.

Census-defined Urban Areas vs. Complainant Ratio

The last metric examined was the percentage of households classified as urban in each zip code to see if a relationship existed between the complainant ratio and urban populations. Linear regression showed the correlation between the two variables as positive, but very weak (r= .06), as indicated in Figure 13. So, while there may be some association between the variables, the data did not support a strong correlation or linear relationship.

Application of Findings and Areas for Additional Research

Analysis of this data showed that the relationship between socioeconomic variables and complainant activity in this data set was quite weak, although positive in the direction that households of higher socioeconomic levels may complain more, as has been noted by Maziul et al. (2005) and Fields (1992). Of the socioeconomic variables, per capita income had the highest relationship to the complainant household ratio, although it was still small. In all cases, the relationships were not statistically significant.

DNL did correlate better with the complainant ratio, which would be similar to earlier findings that indicate as

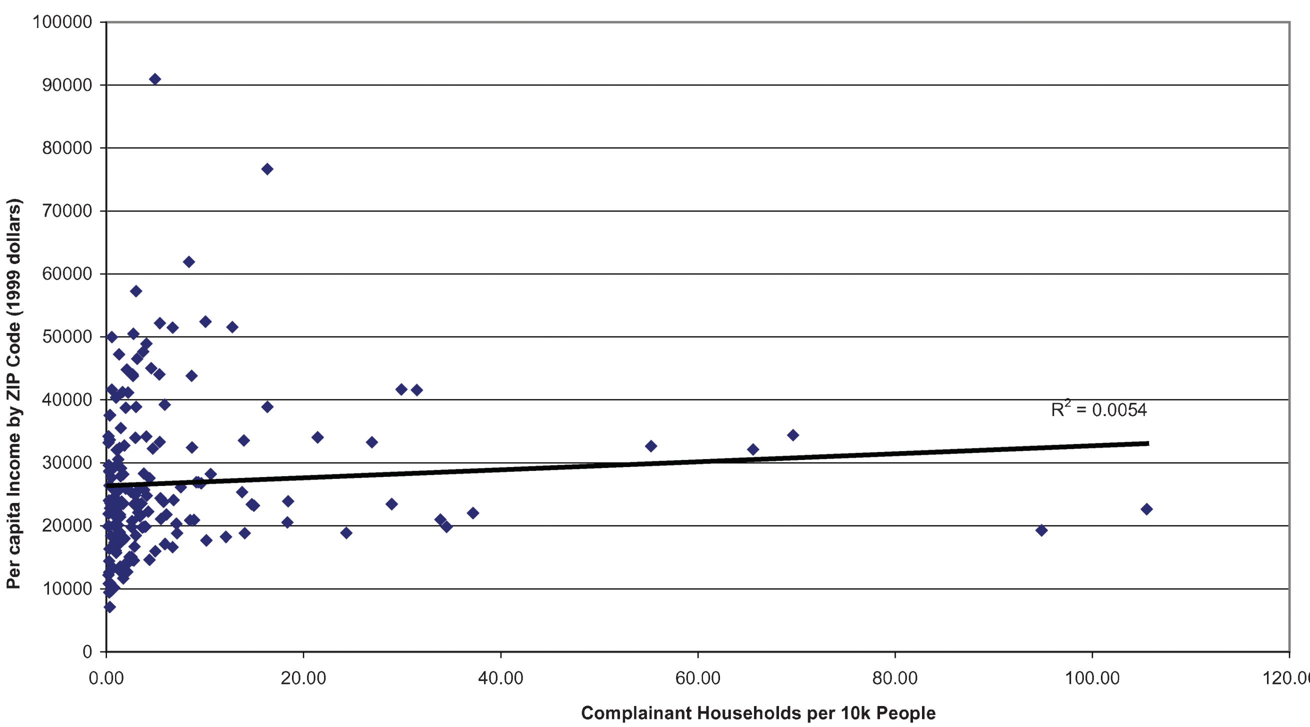

Figure 8. Median per capita income vs. complainant households per 10,000 people.

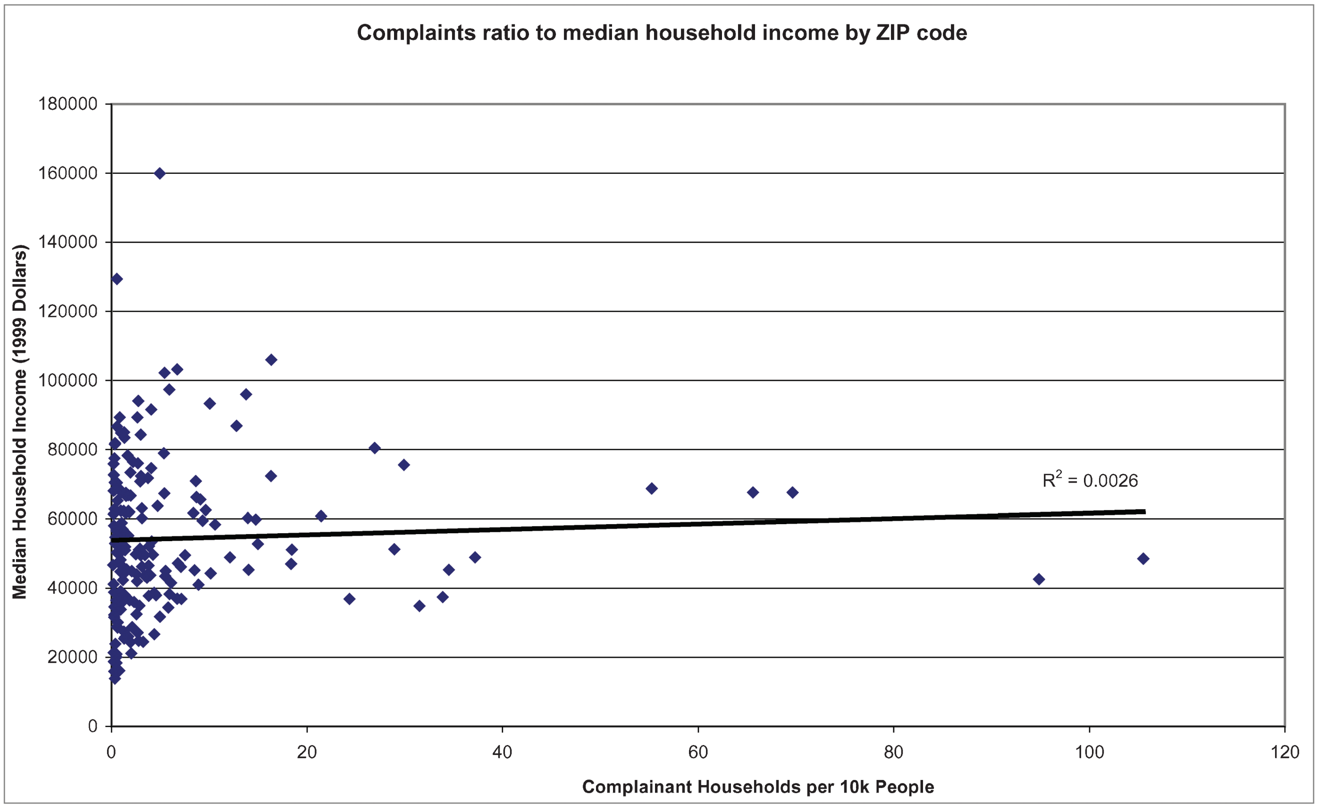

Figure 9. Median household income vs. complainant households per 10,000 people.

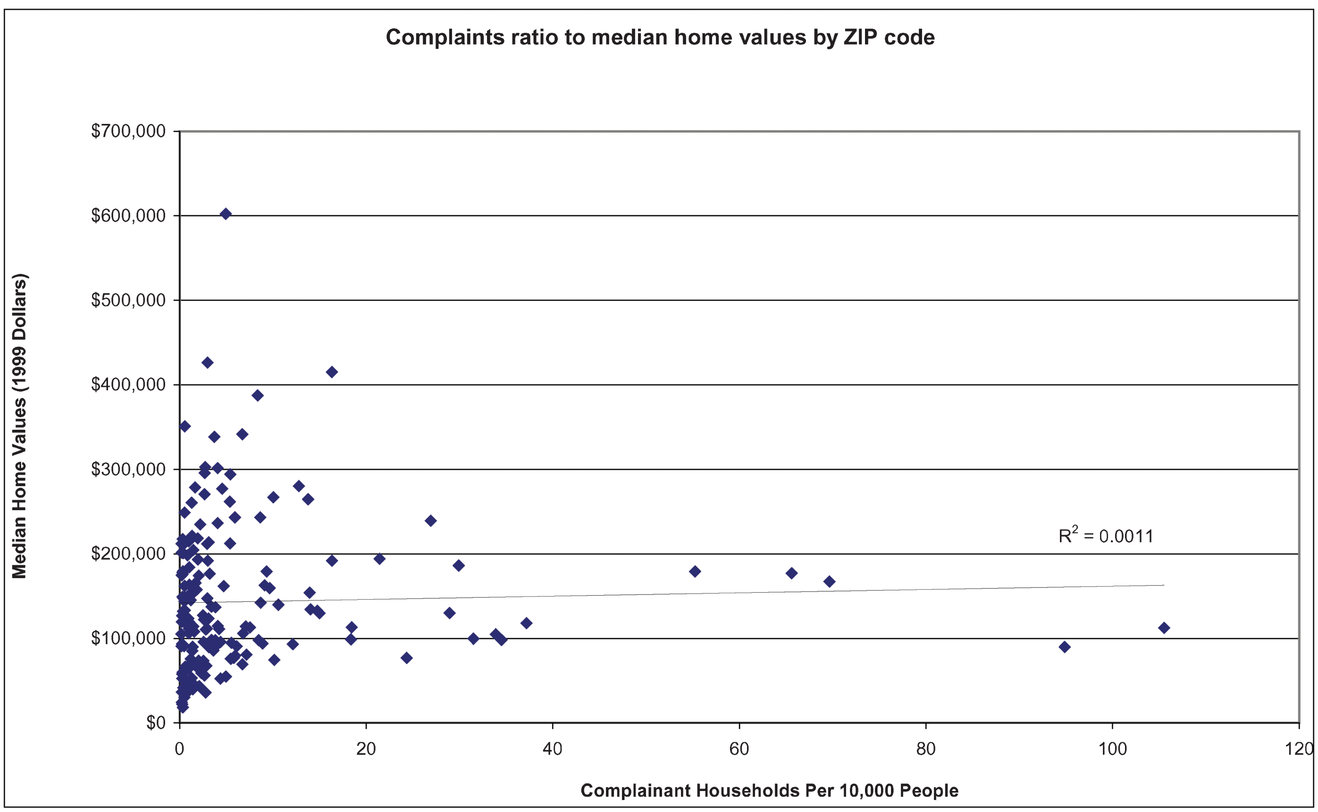

Figure 10. Median home values vs. complainant households per 10,000 people.

Table 2
Mean Number of Complainant Households per 10,000 People by Approximate dB DNL

Approximate Average dB DNL	Mean Number of Complainant Households per 10,000 People
<25	0
25–30	0.97
30–35	1.07
35–40	1.08
40–45	6
45–50	10.13
50–55	9.36
55–60	25.62
>60	0

noise exposure increases, annoyance does as well (Schultz, 1978). However, sound levels clearly were not responsible for all the variance in the relationship, which indicates that other factors besides acoustical exposure were involved. These likely may include some of the social and personal moderators discussed by Fields (1992) and Guski, such as "sensitivity to noise . . . fear of harm connected with the source . . . evaluation of the source . . . and capacity to cope with noise" (1999, p. 48).

Examining of the exact types of noise events likely to trigger complaints is an area where additional research could be useful. For example, it may be that complaints are driven by a stimulus-response relationship to disturbing single event aircraft noise incidents more than as a reaction to long term annoyance. Approximately 16% of complaints at the Philadelphia Airport Noise Office during the period January 1, 2009 to October 31, 2009 were related to go-arounds, during which jet aircraft fly at low altitude, using high engine power over neighborhoods that are not under usual departure paths. Other unusual circumstances, such as weather related flight deviations could create unusually loud events that may trigger a complaint response. Complaints may accurately measure unusual events more than general aircraft noise annoyance.

One application of this hypothesis is that specific measures could be taken to reduce the types of noise events that drive complaints, although it is important to remember that overall annoyance from ongoing noise may not be adequately addressed. Since the literature indicates that annoyance by aircraft is influenced substantially by community perception, reducing complaints provides an opportunity for an airport to quantitatively demonstrate a commitment to noise reduction and to reduce specific loud events that might drive complaints.

This examination of complaint data in the Philadelphia region used rough DNL estimates to see if a possible relationship existed between complaints and DNL exposure and the results indicated that there may be a correlation. It

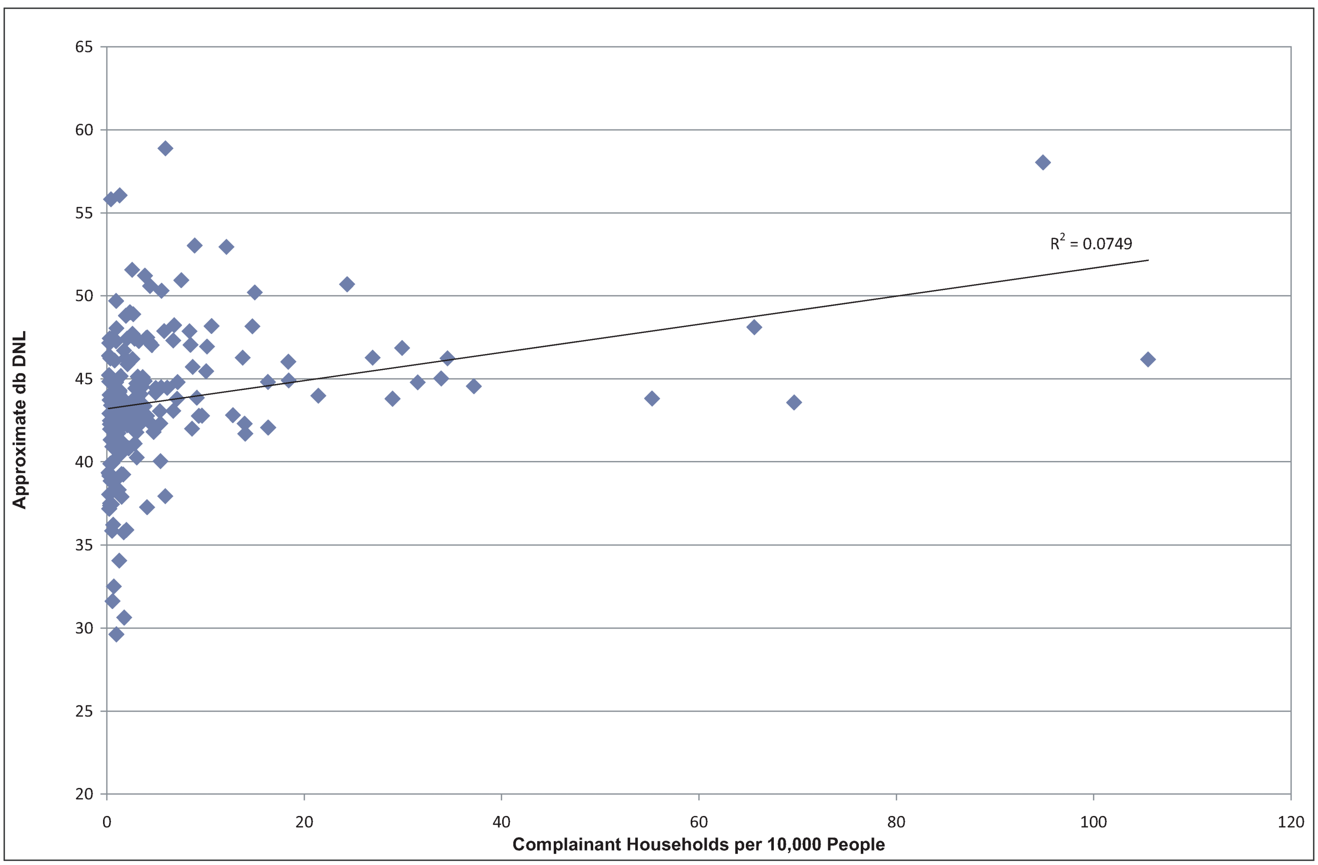

Figure 11. Approximate DNL level vs. complainant households ratio (linear regression).

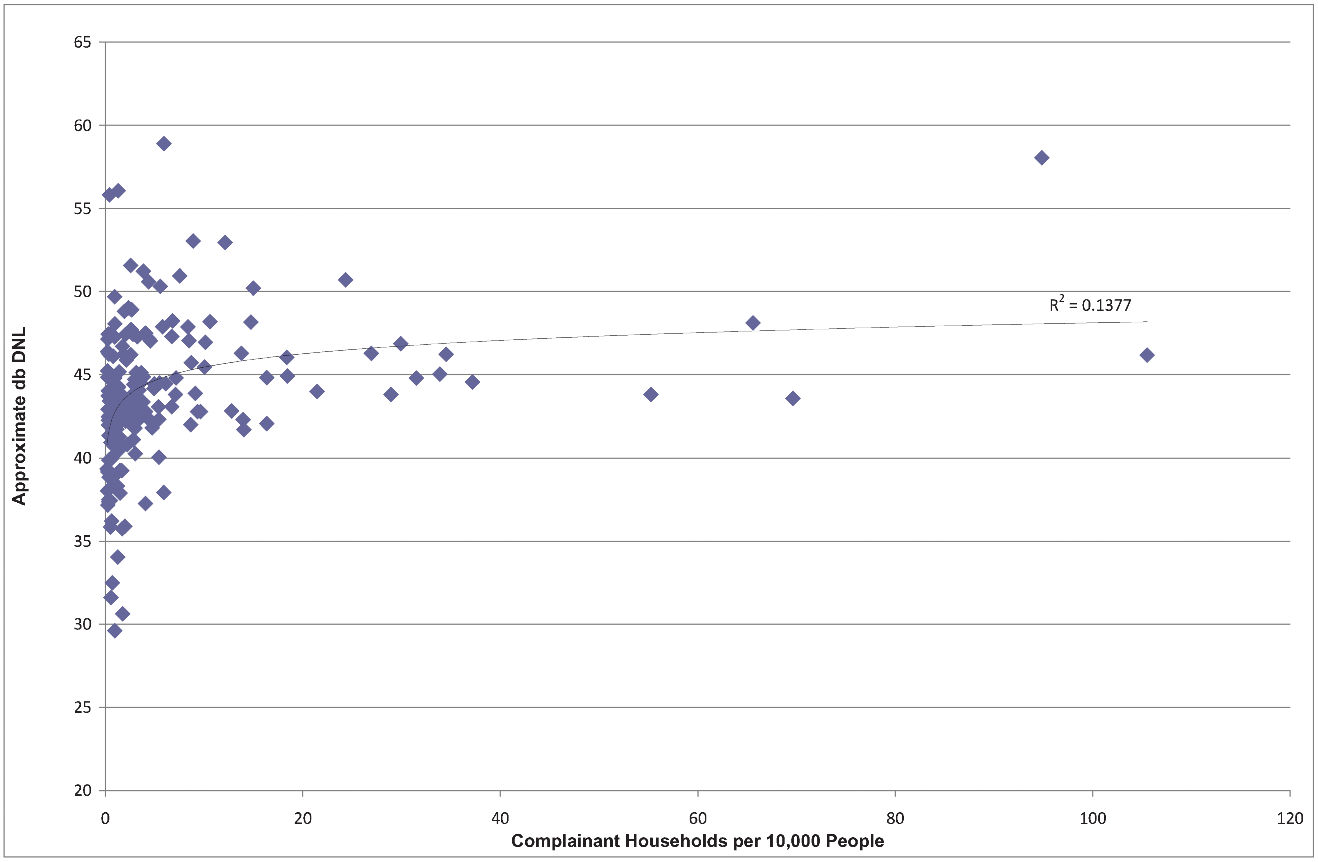

Figure 12. Approximate DNL level vs. complainant households ratio (logarithmic trendline).

then follows that a more precise analysis of this data could be done using the modeled data for each complainant census tract and block. The block by block DNL analysis in the ARD study area provides modeled DNL data that far exceeds what would usually be found in an FAR Part 150 Study. This specific, detailed and widespread data set provides opportunities to study regional noise impacts in areas outside of the 65 DNL contour. In addition, census tract and block data allows for long-term comparisons and trend analysis, as tracts and blocks should remain static while the areas contained within zip codes may change.

Another potential research area is that of studying complaint data and annoyance in areas exposed to 45–65 dB DNL of aircraft noise. It may be that average acoustical exposure becomes a smaller factor as total sound levels decrease, but perhaps single-event noise becomes more problematic as aircraft noise rises and falls above the ambient background noise. This is similar to how a dripping faucet may be extremely bothersome, although the actual acoustical energy of the event is minimal.

Lastly, since complaint data is usually collected and readily accessible at most airports, its value as a metric should be evaluated further. The literature seems clear that complaint behavior is not an accurate gauge of total annoyance, but it does provide an airport with a measure of community concerns and perception.

Conclusion

Annoyance and complaint behavior outside of the 65 dB DNL contour are likely to remain a controversial issue as quieter aircraft are introduced and noise contours shrink, particularly in situations where the number of aircraft movements increases with little or no change to the DNL. Given the 65 dB DNL compatibility threshold, smaller populations within the United States may be eligible for mitigation in the future, although a frequent number of aircraft noise events may continue or even increase in those areas. The large-scale study data from the Airspace Redesign Project provides a distinctive opportunity for examining noise exposure impacts outside of the 65 dB DNL contour over a wide geographic area.

Additionally, future research may be productive in examining the relationship between complainant behavior and community annoyance. It would serve airport operators and noise researchers well to understand what complaints are actually measuring and how that data should be evaluated as part of a greater noise abatement strategy. Even if socioeconomic indicators are not a primary driving factor in annoyance or complaint behavior, the literature seems clear that social and psychological moderators are intertwined with acoustical factors and these relationships warrant additional study and inquiry.

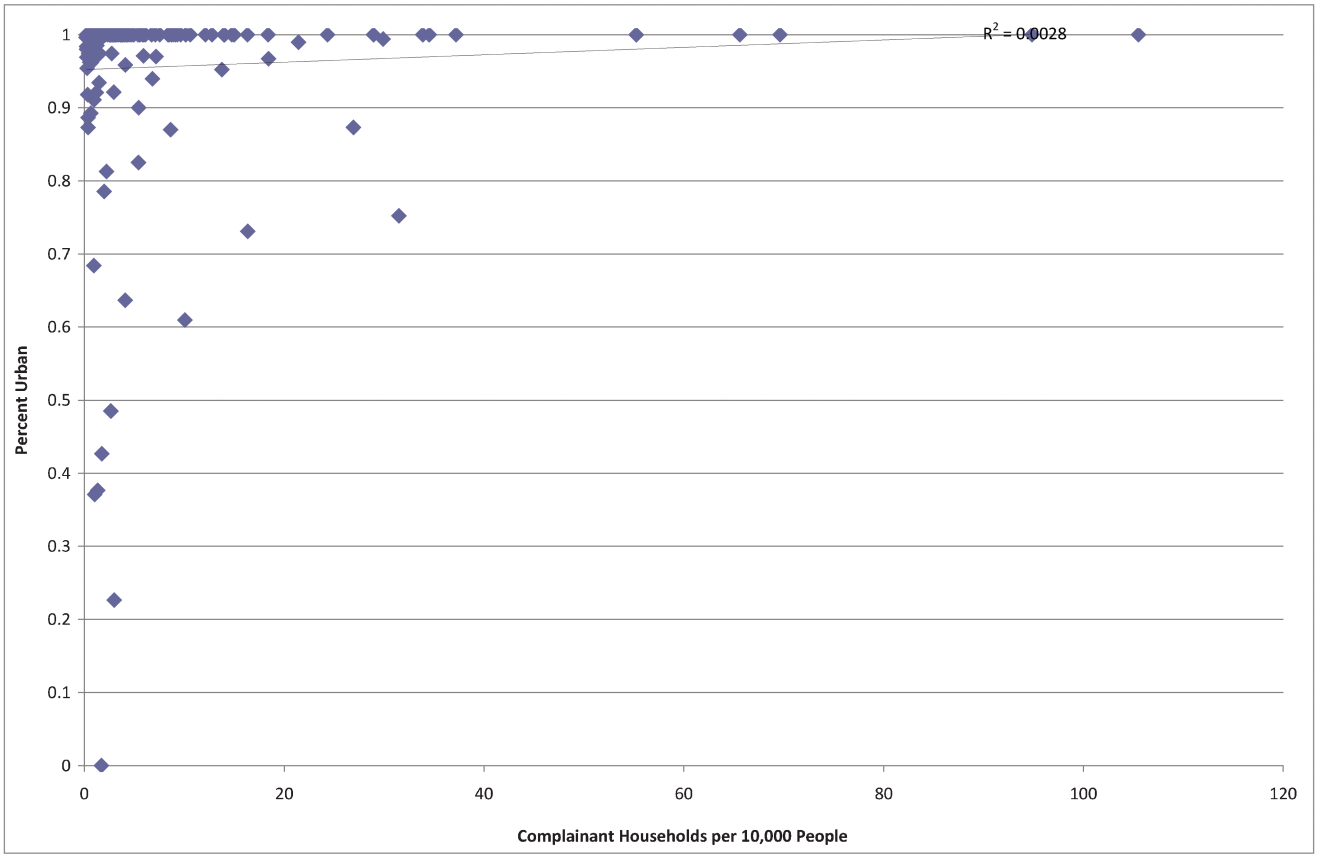

Figure 13. Complainant ratio compared to percent urban population (linear regression).

In summary, analysis of complainant data from the Philadelphia region indicated the strongest relationship was observed between noise exposure as measured by DNL and complaints per zip code. However, the correlation was low enough to suggest that other factors are also influential, such as social and psychological variables. As noted throughout this paper, other research clearly notes that a variety of non-acoustical influences affect noise perception. However, in this data set, the particular socioeconomic metrics examined, such as income and housing prices, showed weak correlations to complainant activity. Although these metrics were slightly positive in the indication that as measures of wealth increased, the complainant ratio did as well, other factors should be considered and studied further.

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